



EMSP

Environmental Management Science Program

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ENGINEERING SCIENCE

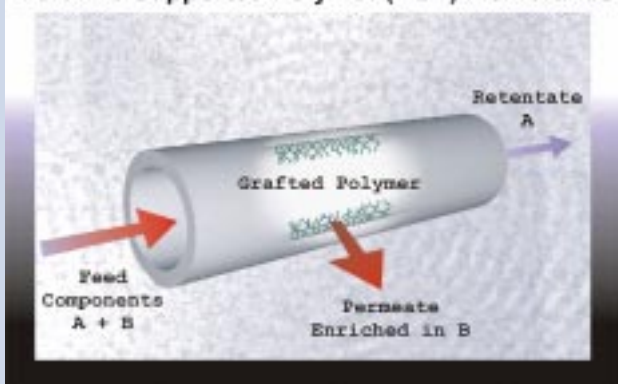
FUNDAMENTAL STUDIES IN ENGINEERING SCIENCE CAN LEAD TO THE DEVELOPMENT OF NEW IN-SITU REMEDIATION TECHNOLOGIES

This science category includes bioengineering research, ultrasonic irradiation applications, and process/modeling design. The projects described here are associated with environmental remedial action, and each explores a technique with potential subsurface applications:

- As ultrasonic irradiation results in remarkably high temperatures in microbubbles in an otherwise cool liquid, organic contaminants in water can be decomposed by this technique. One EMSP project is focused on fundamental studies of the mechanism of the process, while another is exploring in-situ application of the technique to help remove organic compounds that are difficult to treat by other techniques.
- An electrochemical process for the in-situ treatment of soils contaminated by mixed wastes is the subject of another project. Organic compounds and metal ions can be concentrated near electrodes placed in the soil, and in-situ generation of hydrogen peroxide can be used to oxidize a number of hazardous organic compounds.
- Possible applications of nuclear magnetic resonance imaging for measurements of subsurface water content are being explored by a collaborative university/industry group. The capabilities of this technique, which originated in Russia, are being investigated.
- The design of ceramic-supported polymer membranes has led to improved methods for removing organic contaminants from water, and the focus of one project is to custom design a new class of task-selective membranes.
- Potential biofiltration methods are being investigated for emission-free destruction of organic wastes, and the objective of one project is to make long-term operation of biofilter units possible.

All major DOE sites have cited needs for improved methods for remediating hazardous organic compounds, usually chlorinated hydrocarbons. The projects discussed here may contribute to such improved characterization or treatment methods. As several sites, particularly Hanford, have Site Technology Coordinating Group needs statements related to remediating metals in the subsurface, basic research in this area is also a high-priority need.

Ceramic-Supported Polymer (CSP) Membranes



Membranes for Chemical Separations

The University of California group is developing ceramic-supported polymer membranes that can be used for organic-water and organic-organic separations.

PROBLEMS/SOLUTIONS

- Every major Department of Energy (DOE) site has a need to remove hazardous organic liquids from the subsurface. Effective in-situ treatments could reduce the time required for the current pump-and-treat methods by decades.
- Hanford Site Technology Coordinating Group needs include in-situ remediation of chromium, strontium, uranium, cesium, cobalt, and plutonium. Electrochemical techniques are being explored for possible field applications for a variety of metal ions.
- The design of improved groundwater remediation systems requires knowledge of the distribution of water in the subsurface. One EMSP project is investigating the applicability of surface nuclear magnetic resonance imaging for this task.
- Biofiltration is an attractive method for emission-free destruction of organic waste, but current systems tend to have short useful lifetimes. Studies of the biofiltration process may lead to long-term use of biofilters in industrial settings.

ANTICIPATED IMPACT

- The United States dominates the world market in ultrasonic equipment, which is available at modest costs for large-scale liquid processing. Applications for removing organic compounds from water could enhance this already vital industry.
- The Savannah River Site estimates that current pump-and-treat methods will need to process more than 40 billion gallons of water for 30 to 200 years. Any viable in-situ methods that emerge from EMSP projects could have a major impact on the associated lifetime costs.
- The Hanford Site has more than 14 million cubic yards of soil that are contaminated with radionuclides. In-situ technologies that are less expensive than the current cost of \$105/cubic yard for excavation and disposal are needed, and even modest cost reductions could have a significant impact.

Ultrasonic Irradiation for Organic Waste Remediation

The University of Illinois project is exploring the fundamental processes that occur when organic compounds are exposed to high-intensity ultrasound. Using the emission of light that accompanies ultrasonic irradiation to measure, for the first time, the temperatures achieved in microbubbles, they have found temperatures as high as 5,000°C with pressures as high as 1,000 atm in an otherwise cool liquid. Thus, many organic compounds that dissolve in water may be decomposed in much the same manner as they would be by heating the bulk sample to very high temperatures. These sonochemistry studies will be applied to designing and testing large-scale systems for contaminated water remediation.

In-Situ Treatment of Contaminated Groundwater and Soils

The Argonne National Laboratory/California Institute of Technology/Stanford University project is investigating an integrated system that combines in-well sonication, in-well vapor stripping, and in-situ biodegradation to remediate contaminated groundwater and soils. The goal of the project is to use in-well acoustic cavitation (sonication) to (1) remove volatile organic compounds (VOCs) and (2) partially degrade semivolatile organic compounds, thus converting them into compounds that are more amenable to both vapor stripping and biodegradation. The team is also working on developing a three-dimensional computer simulation model to describe the integrated system for field operations. A pilot-scale system will be tested for application in remediating subsurface contaminants commonly encountered in the DOE complex.

The University of Delaware group is investigating electrochemical processes for in-situ treatment of contaminated soils. The motion of ions in an electric field results in transfer of water toward an electrode, and many organic pollutants are carried with the transferred water. It has been found that control of the pH with non-toxic sodium acetate and acetic acid improves the efficiency of this process, with as much as 90-percent organic removal in 15 days. Electrochemical generation of hydrogen peroxide can also provide an effective means of mineralizing many chlorinated hydrocarbons using a well-known oxidation process that requires peroxide along with an iron salt.

After use of vapor stripping techniques to remove VOCs from the subsurface, the next step is the emission-free destruction of those VOCs. The Oak Ridge National Laboratory group is investigating the fundamental properties of biofiltration units, which pass the vapor-phase VOCs through a tube containing microbes that can metabolize them. This group has studied the means to control biofilm overgrowth, predictive models for system operation, isolation and identification of the microorganisms, and other problems related to long-term use of effective biofiltration technology.

Nuclear Magnetic Resonance (NMR) Imaging of Water in the Subsurface

As pathways for contaminant migration are generally related to pathways for water migration, techniques more reliable than divining rods are needed to measure water content in the subsurface. The technique of NMR imaging is well known from medical applications, but imaging of subsurface water relies on the use of the earth's magnetic field and is much less sensitive. The New Mexico Institute of Mining and Technology/Blackhawk Geometrics team is investigating a surface NMR technique that was first implemented by Russian scientists. They have found that NMR measurements can determine water distribution in coarse-grained aquifers. However, interference from power lines in urban settings, the presence of minerals with a high magnetic susceptibility, and the inability to detect water in fine-grained sediments also hinder use of the technique.

Membranes for Chemical Separations

The separation of chemical species from each other is frequently the most energy-expensive step in chemical processing and remediation processes. The University of California group is developing ceramic-supported polymer (CSP) membranes that can be used for organic-water and organic-organic separations. The mechanical strength of the CSP membrane is provided by the ceramic support, and the selectivity for separations is provided by the polymer layer. Applications have included treatment of oil-in-water emulsions and removal of trichloroethylene and chloroform from aqueous solutions by pervaporation.

PROJECT TEAMS

(EMSP AWARD NUMBER)

- University of Delaware (54661)
- New Mexico Institute of Mining and Technology
Blackhawk Geometrics
(54857)
- University of California – Los Angeles (54926)
- Oak Ridge National Laboratory (55013)
- University of Illinois (55211)
- Argonne National Laboratory
California Institute of Technology
Stanford University
(55374)



FOR ADDITIONAL INFORMATION ABOUT THE EMSP, PLEASE CONTACT ONE OF THESE REPRESENTATIVES:

Mark A. Gilbertson
Director, Office of Science & Risk
(202) 586-7150
!emsp@id.doe.gov
www.em.doe.gov/science

Tom Williams
EMSP Director, DOE-ID
(208) 526-2460
!emsp@id.doe.gov
www.id.doe.gov/emsystems/emsp

Roland Hirsch
EMSP Director, Office of Science
(301) 903-9009
!emsp@id.doe.gov
www.er.doe.gov